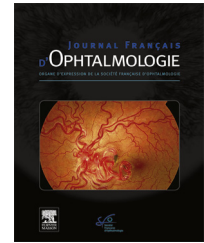Disponible en ligne sur

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ORIGINAL ARTICLE

In vivo characterization of lamina cribrosa pore morphology in primary open-angle glaucoma

Caractérisation in vivo de la morphologie des pores de la lame criblée dans le glaucome primitif à angle ouvert

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Summary
Purpose. — To characterize the in vivo morphology of human lamina cribrosa pores in healthy and glaucoma eyes.
Patients and methods. — In this cross-sectional, observational study, a flood-illumination adaptive optics fundus (FIAO) camera was used to perform in vivo, high-resolution, noninvasive imaging of the optic disc and lamina cribrosa in 30 patients diagnosed with primary open-angle glaucoma (POAG), in 15 healthy controls and in 14 healthy subjects with at least one direct relative with POAG. Two masked graders measured each visible lamina cribrosa pore along the major and minor axes in order to categorize pores as oval (minor/major axis ratio < 0.75) or round. We used these same measurements to calculate pore surface area as a best-fit oval.
Results. — Lamina cribrosa pores were visible in 95.2% of the subjects. In 52% of controls, the pores were visualized under the neuroretinal rim. In POAG patients, 78% of visible pores had an oval shape versus 19.4% in controls ($P < 0.01$). Average pore surface area was significantly different (1561 px^2 versus 724 px^2; $P < 0.01$). In healthy subjects with at least one direct relative with POAG, 21% had pores with an appearance comparable to that of subjects in the glaucoma group.

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Conclusion. — On average, lamina cribrosa pores are elongated in POAG eyes and also in healthy eyes of POAG relatives. In vivo characterization of lamina cribrosa pore morphology by FIAO imaging may enhance our understanding of glaucoma, and offer new means for its early detection.

MOTS CLÉS
Glaucome primitif à angle ouvert ;
Lame criblée ;
Optique adaptative

Résumé
Objectif. — Caractériser la morphologie in vivo des pores de la lame criblée de nerfs optiques de patients glaucomateux.
Patients et méthodes. — Dans cette étude observationnelle transversale, une caméra à optique adaptative a été utilisée pour effectuer in vivo une imagerie non invasive, de haute résolution du disque optique et de la lame criblée, chez 30 patients diagnostiqués avec un glaucome primitif à angle ouvert (GPAO), chez 15 témoins sains et chez 14 sujets sains avec au moins un parent direct atteint de GPAO. Les données ont été recueillies en double insu, chaque pore visible de la lame criblée a été mesuré, le long des axes majeur et mineur afin de catégoriser les pores comme ovale ou rond. Nous avons utilisé ces mêmes mesures pour calculer la surface des pores.
Résultats. — Chez 95,2 % des sujets, les pores de la lame criblée étaient visibles. Chez 52 % des témoins, les pores ont été visualisés sous l'anneau neurorétinien. Chez les GPAO, 78 % des pores visibles avaient un aspect ovale contre 19,4 % chez les témoins ($p < 0,01$). La surface moyenne des pores était significativement différente (1561 px^2 versus 724 px^2 ; $p < 0,01$). Chez les sujets sains ayant au moins un parent direct atteint d'un GPAO, 21 % avait des pores avec un aspect comparable à celui de sujets dans le groupe glaucome.
Conclusion. — Les pores de la lame criblée des patients GPAO ainsi que ceux des yeux des patients apparentés sont ovalaires. Ainsi, la caractérisation in vivo de la morphologie des pores de la lame criblée en optique adaptative pourrait améliorer notre compréhension du glaucome et offrir de nouveaux moyens pour sa détection précoce.

Introduction

Primary open-angle glaucoma (POAG) is a leading cause of blindness worldwide. It is a progressive optic neuropathy with structural changes in the optic disc, retinal nerve fiber layer (RNFL) and associated functional loss [1]. The mechanisms of glaucomatous alterations are still poorly understood, but the role played by the lamina cribrosa (LC) in the optic nerve head seems essential [2]. The LC is a three-dimensional porous structure composed of flexible collagenous tissue that supplies nutrition to the RNFBs via the connective tissue composed of astrocytes and a microvascular network located between the pores of the LC [3]. The LC is a dynamic structure may be remodeled in response to the intraocular forces to which it is subjected [4,5]. The assumed biomechanical response is cupping and sheering, which leads to changes in the LC surface in turn modifies the morphology of LC pores [6—9]. Deformation of LC pores is believed by some to be at the origin of the degradation of RNFBs in that it disrupts the axonal distribution as well as oxygenation and nutritional blood flow [10,11]. In glaucomatous patients, the surface area and elongation of LC pores were measured in vivo using adaptive optics scanning laser ophthalmoscopy (AO-SLO) [12], enhanced depth imaging optical coherence tomography (EDI-OCT) [13,14], with clearly different morphological aspect between the healthy and glaucomatous LC, confirming previous studies results. Three-dimensional models of the LC have been developed to analyze its curvature and the subsequent changes in pore morphology [15,16]. The morphology of the LC pores can well be analyzed with an en face technology [17,18]. Studying the complex structure of the LC in vivo has therefore become central to glaucoma research [16,19,20].

Adaptive optics (AO) is a technology originally developed for astrophysics to improve the resolving power of ground-based telescopes. In ophthalmology, it has been used to measure and correct for the optical aberrations to provide near diffraction-limited imaging of the outer retina. It has already been successfully used in combination with OCT, SLO [21], and a fundus camera (flood-illumination AO) [22]. AO-enhanced imaging technologies have been shown to be reproducible and reliable for measuring the LC pores [23].

In the present study, we observed the LC using a flood-illumination AO (FIAO) camera. We sought to compare the morphology of LC pores between controls, POAG eyes and healthy subjects with at least one direct relative in the ascending line with POAG.